TRACE Instrument

CONTAMINATION CONTROL PLAN
TRA-271001/A

Rev. B (21.Nov.97)

PREPARED UNDER
CONTRACT NAS 5-38099

PREPARED BY:

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Change Control Summary Page

Section	Change	Date/Rev.
Rev. B changes	**REASON FOR REVISION:** Replace TBDs with document numbers, add relevant documents that have been prepared, eliminate references to irrelevant or inappropriate documents	21.Nov.97
N/A	Add change control summary page	12.Nov.97
Title Page	Revise and update signature lines	19.Nov.97
2.1.3.3	Delete references SAO OWS plan, and Thermal Vacuum Bakeout Plan. Insert Instrument and S/C TV/TB document references and numbers. Insert TRACE Purge procedure &number. Insert IICD (SAO) document Number	18.Nov.97
2.1.3.3	Add correct document numbers/titles for purge plan and OWS sampling plan	18.Nov.97
2.3	Update Acronym List	19.Nov.97
3.1.1.3	Delete place-holder for solar cell EOL power output.	18.Nov.97
3.3.1.3	Insert OWS sampling plan document number	18.Nov.97
Table 3-4	Insert hardware cleanliness levels for Manufacturing-level (FCA, Entrance filters, Guide Telescope,	18.Nov.97
4.0	Delete TBD	18.Nov.97
4.2.4.1	Delete reference to XWS document, insert document numbers, delete TBD and change cleanliness level for purge-cart plumbing, delete TBDs for purge interrupts. Delete reference to pre-launch interrupt.	18.Nov.97
4.3.5	Delete reference to OWS sampling for mirrors (XWS plan), insert OWS plan document number	18.Nov.97
4.7.3	Delete TBD	18.Nov.97
4.9.2	Insert document number	18.Nov.97
4.11	Delete TBDs and reference to Thermal Vacuum Bakeout plan. Insert Instrument and s/c TV/TB plan document numbers.	18.Nov.97
4.11.2.1	Delete TBD	18.Nov.97
4.12	Delete TBD	18.Nov.97
4.13	Delete TBD	18.Nov.97

Section 1

INTRODUCTION

The TRACE science investigation explores the structure and the evolution of the Sun's fine-scale magnetic fields via quantitative imagery of photospheric, chromospheric, transition region, and coronal plasmas. The instrument includes a primary and secondary mirror system, entrance filters, optical filters and a CCD camera.

1.1 Objective

The objective of TRACE Instrument Contamination Control Plan, TRA 271001 (TRACE CCP), is to assure that the effects of contamination do not significantly compromise TRACE mission performance. TRACE CCP documents the design, process, facility, and equipment features which are implemented in the development, fabrication, storage, transportation, integration, testing, captive carry, launch, and operation of TRACE. During implementation of numerous space programs, LMMS and NASA have developed an extensive background in contamination control technology. This technology and experience will be employed during mission and hardware design, and hardware manufacture, assembly, and systems test of TRACE elements.

1.2 Scope

TRACE Instrument CCP includes both documentation of contamination control requirements and definition of contamination control implementation methods which are necessary to assure that TRACE mission performance objectives are met. The plan includes instrument and mission design phases; instrument, sub-system, and component manufacture, assembly, integration, storage, transportation, and test phases; and the processes, facilities, and ground support equipment employed in each phase. The plan addresses potential contamination by both molecular deposits and particles. Specific, detailed contamination control methods and procedures are developed in parallel with program maturity and hardware development, and it is intended that this document be revised to meet TRACE Instrument requirements as they evolve.

1.3 Approach

TRACE Instrument contamination control plan is a systematic application of current contamination control technologies in all phases of design, fabrication, assembly, transportation, integration, test, and flight-operations to assure that mission objectives are not limited by the effects of contamination. Instrument hardware design, materials, and on-orbit operations limits the exposure of critical surfaces to molecular contamination which would degrade optical throughput; the facilities, equipment, and procedures used throughout ground-operations are developed to limit exposure to environmental, operational, and self-generated contaminants; and cleaning, testing, inspection, and monitoring are

Section 2

APPLICABLE DOCUMENTS AND DEFINITIONS

2.1 Documents
The following documents are considered a part of this plan to the extent specified herein. Unless otherwise specified, the latest revision applies.

2.1.1 Specifications
2.1.1.1 LMMS

LAC 0170	General Cleaning of Parts and Surfaces
LAC 3026	Environmental Control
LAC 3150	Contamination Control, Process Specification
LAC 3155	Precision Cleaning of Exterior Surfaces for Contamination Control

2.1.2 Standards
2.1.2.1 Federal

FED-STD-209	Cleanroom and Work Station Requirements, Controlled Environment

2.1.2.2 Military

MIL-STD-889	Dissimilar Metals
MIL-STD-1246	Product Cleanliness Levels and Contamination Control Program

2.1.2.3 LMMS Product Assurance

Standard 8620-Q002	Certification of Cleanrooms
Standard 8650-Q026	Certification of Personnel for Hardware Cleaning and Hardware Cleanliness Verification

2.1.3 Other Publications
2.1.3.1 NASA Documents

JSC SP-R-0022	Vacuum Stability, Requirements of Polymeric Material for Spacecraft
JSC SN-C-0005	Contamination Control Requirements
NASA-RP-1124	Outgassing Data for Selecting Spacecraft Materials

2.1.3.2 American Society for Testing and Materials

ASTM F24	Measuring and Counting Particulate Contaminants on Surfaces
ASTM F303	Standard Practice for Sampling Aerospace Fluids From Components

ASTM E1559 Standard Test Method for Contamination Outgassing Characteristics of Spacecraft Materials

Section 2

APPLICABLE DOCUMENTS AND DEFINITIONS (Continued)

2.1.3.3 TRACE Project Documents

TRA-271002	Product Assurance Implementation Plan; Section 9, Contamination Control Requirements
TRACE-SPEC-011	TRACE Contamination Requirements and Control Plan
TRACE-ICD-006	Contamination Control Interface Control Document Between the TRACE Spacecraft Bus and Instrument
TD-0286	Pegasus Contamination Control Plan: NASA M 5.5 Missions
TRA-271016	TRACE Optical Witness Sample Monitoring Plan for Instrument Interior
TRA-141007	Internal Interface Control Document for the TRACE Primary Mirror Assembly
TRACE-PROC-091	TRACE Launch Site Purge Procedure
TRA-271011	TRACE Instrument Thermal Balance and Thermal Vacuum Cycling Test Plan
TRACE-TEV-028	TRACE Observatory Thermal Vacuum and Thermal Balance Test Plan

2.2 DEFINITION OF TERMS

To promote mutual understanding of terms in this plan, definitions of terms used to describe contamination control are provided as follows:

AREA COVERAGE The effective physical area of a surface covered by particulate contaminants. The calculated percent-area-coverage (% AC) takes into consideration the effect of aspect ratios of different particle size ranges.

ASPECT RATIO Ratio of 'average maximum dimensions' of the projected area of an elliptical particle to its projected area 'average minimum dimensions'.

CLEANLINESS LEVEL An established maximum of allowable contaminants based on size and number of particles and/or quantity or thickness of molecular contamination on a given area or in a specific volume. Specified cleanliness levels range from 'generally clean' (GC) to 'precision clean' in accordance with MIL-STD-1246 (i.e.: Level 100A, Level 300B, etc.) and JSC SN-C-0005 (e.g.: Visibly Clean (VC), VC Sensitive, and VC Highly Sensitive). See Table 2-2 for a tabulated summary of product cleanliness levels.

CLEANROOM An enclosed area where temperature, humidity, and airborne contaminants are controlled as required. Cleanrooms are classified by numbers such as 100, 1,000, 10,000, etc., in accordance with FED-STD-209 which describes the maximum number of particles, larger than 0.5 μm in size, permitted per cubic foot of air.

CONVENTIONAL INDUSTRIAL AREA An area where contamination is not controlled.

CONTAMINATION Any unwanted material that adversely affects component, sub-system, or system performance, reliability, or operation.

CONTAMINATION BUDGET ALLOCATION The allowable degradation for a specific component in a series (e.g.: optical path) or for a specified sequence of events.

CONTAMINATION BUDGET The itemized summary of contamination degradation for a given critical hardware item, as a distribution across all phases from manufacture through the end of its performance lifetime.

CONTAMINATION CONTROL Organized action to control the level of contamination on critical hardware.

other extraneous contamination. This level can be achieved by washing, wiping, blowing, vacuuming, brushing, or rinsing. This level shall not be designated for hardware that is sensitive to contamination, or that has the potential to contaminate hardware that is sensitive to contamination.

GOOD HOUSEKEEPING AREA An area where good housekeeping practices produce visible cleanliness and orderliness.

GROSS CLEANING A cleaning operation performed to achieve a level of cleanliness as part of a good workmanship and good housekeeping practice (e.g., removal of oils, grease, oxide films, etc.). Gross cleaning does not usually require verification beyond visual appearance as observed without optical aids, except normal vision or vision corrected to normal per LAC 0170.

MICRON (µm, micrometer) A unit of measurement equal to 10^{-6} meter, 3.9 x 10^{-5} inch, e.g., 25 µm is approximately 0.001 inch.

MOLECULAR CONTAMINATION Organic thin film deposits on surfaces as a result of direct application of oils and greases, and/or as the result of adsorption or condensation of outgassed volatile organic materials.

NONVOLATILE RESIDUE (NVR) Soluble material remaining after evaporation of a volatile liquid usually measured in milligrams per unit area (or volume, for liquids).

NVR FALLOUT Nonvolatile residues collected from facilities environments onto witness samples, such as per ASTM E1234 and ASTM 1235, or by other approved methods.

PARTICLE A discrete mass of solid or liquid matter with observable length, width, and thickness. Particles on precision cleaned surfaces are usually measured in microns (µm).

PARTICLE SIZE The apparent maximum linear dimension (in µm) of a particle.

PRECISION CLEANING Cleaning of hardware surfaces by approved engineering methods and procedures to meet specific cleanliness criteria and generally associated with attaining specific cleanliness levels.

PRECISION CLEANLINESS The degree of freedom from contaminants that cannot normally be detected by visual means. Detection and measurement of precision cleanliness requires special equipment and techniques.

PRECISION CLEAN PACKAGING Packaging or protection used to preserve precision cleanliness for a specific period and condition.

PURGE To flow gas through a system (or line, tank, instrument, etc.) for the purpose of removing a residual fluid, providing a barrier of clean, dry gas to protect critical surfaces from contamination, or to providing a positive flow of gas from some opening in the system.

SOLVENT FLUSHING A method of cleaning surfaces where a stream of filtered solvent under pressure is directed against a surface to dislodge and flush away unwanted foreign material.

VALIDATED CLEANING PROCESS A cleaning process previously evaluated on representative hardware to prove the cleaning procedure is, in fact, satisfy the required cleanliness level.

TOTAL SOLIDS The residue from a known volume of liquid which has been evaporated to dryness under controlled conditions in an oven.

OUTGASSING RATE (TOTAL) (OGR_{tot}) Rate of evolution of all material from any surface or from an organic material under thermal vacuum conditions. In testing (ASTM 1559) this is measured by the rate of condensation of material onto a TQCM held at 80K.

OUTGASSING RATE ($OGR_{t^{\circ}C}$) Rate of evolution of materials from any surface or from an organic material which are condensable at temperature t.

(VC & VCHS) VISIBLY CLEAN Absence of particles and molecular contaminants when viewed from a distance of 6 to 18 inches with normal unaided eyes (except vision correction lenses) under 100 foot-candle or better of illumination. (Also known as "highly sensitive" VCHS.)

Table 2-2a. Derivation of Particulate Cleanliness Levels (MIL-STD-1246C)

Cleanliness Level	Size Range (µm)	Max. Particles, Per 1.0 sq ft	0.1 sq m
1	>1	1	1
5	1 - 2	1	1
	3 - 4	1	1
	>5	1	1
10	1 - 2	1	2
	3 - 5	4	4
	6 - 10	2	2
	>10	1	1
25	3 - 5	30	32
	6 - 15	20	21
	16 - 25	2	3
	>25	1	1
50	6 - 15	141	152
	16 - 25	18	19
	26 - 50	6	7
	>50	1	1
100	6 - 15	1520	1644
	16 - 25	187	202
	26 - 50	67	72
	51 - 100	10	11
	>100	1	1
200	16 - 25	2949	3180
	26 - 50	1070	1156
	51 - 100	154	167
	101 - 200	15	16
	>200	1	1
300	26 - 50	6434	6950
	51 - 100	926	997
	101 - 250	93	101
	251 - 300	1	1
	>300	1	1
500	51 - 100	10717	11610
	101 - 250	1074	1162
	251 - 500	25	27
	>500	1	1
750	51 - 100	86888	95370
	[illegible]	[illegible]	[illegible]

Table 2-2b. NVR Cleanliness Levels
(MIL-STD-1246C)

Cleanliness Level	NVR Limit, Area mg/0.1 sq m	NVR Limit, Vol mg/l
A/20	0.05	0.5
A/10	0.1	1.0
A/5	0.2	2.0
A/2	0.5	5.0
A	1.0	10.0
B	2.0	20.0
C	3.0	30.0
D	4.0	40.0
E	5.0	50.0
F	7.0	70.0
G	10.0	100.0

2.3 ABBREVIATIONS AND ACRONYMS

Å	Angstrom
ASSY	Assembly
ASTM	American Society for Testing and Materials
CCD	Charged Coupled Device
CCE	Contamination Control Engineer
CCE&L	LMMS Contamination Control Engineering & Laboratory
CCP	Contamination Control Plan
CVCM	Collectable Volatile Condensable Material
DPU	Digital Processing Unit
EUV	Extreme Ultraviolet
FCA	Filter Chamber Assembly
Fed-Std XXX	Federal Standard
FTIR	Fourier Transformer Infrared Spectroscopy
GIDEP	Government/Industry Data Exchange Program
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
$\mathbf{H_20}$	Water
IPA	Isopropyl Alcohol
IICD	Internal Interface Control Document
JSC	Johnson Space Center
LAC	Lockheed Aircraft Corporation
LFB	Laminar Flow Bench
LFT	Laminar Flow Tent
LMMS	Lockheed Martin Missiles & Space
MDI	Michelson-Doppler Interferometer
MEK	Methyl Ethyl Ketone
mg	milligram
MIL-STD XXX	Military Standard
MLI	Multi-layer Insulation
µm	micrometer (micron)
MSFC	Marshall Space Flight Center
MTK	Molecular Transport Kinetics
MUA	Material Usage Agreement
N/A	Not Applicable

PA-STD	Product Assurance Standard
PFO	Particle Fallout
RGA	Residual Gas Analyzer
SMEX	Small Explorer
SAW	Surface Acoustic Wave Quartz Crystal Microbalance
TBD	To Be Determined

2.3 ABBREVIATIONS AND ACRONYMS (Continued).

TBR	To Be Resolved
TML	Total Mass Loss
TNTC	Too Numerous to Count
TQCM	Thermal-Controlled Quartz Crystal Microbalance
TRACE	Transition Region And Coronal Explorer
USAF	United States Air Force
UV	Ultraviolet
VCHS	Visibly Clean Highly Sensitive
VCM	Volatile Condensable Materials
VODKA	Vacuum Outgassing/Deposition Kinetics Apparatus
V/UV	Vacuum Ultraviolet Spectrophotometer

Section 3

CONTAMINATION CONTROL REQUIREMENTS

3.1 Program Cleanliness Requirements
The cleanliness requirements for TRACE are flowed down from the following documents:
- TRACE PAIP TRA-271002 Section 9, Contamination Control Requirements
- TRACE-SPEC-011 TRACE Contamination Requirements and Control Plan

3.1.1 Performance Requirements
Specific requirements contained in this document are developed to achieve the following performance requirements.

3.1.1.1 Instrument Optical Performance Requirements
- EOL performance requirements within the optical path is = 50% total throughput degradation for each of the specified observation-wavelength bands (**not** at Lyman alpha).
- EOL performance requirement for CCD sensor pixel outage = 0.1% total obscuration by surface area coverage.

3.1.1.2 Thermal Performance Requirements
- EOL operating temperature = 40ºC. As a result of instrument design, flight configuration, and attitude, contamination is not expected to adversely effect the thermal control of this instrument or spacecraft.

3.1.1.3 Spacecraft Power Supply Performance Requirements (imposed).
- EOL solar-cell power output must remain within s/c performance specifications. Outgassed material from electronics are restricted to assure that thermal surfaces and solar cells maintain performance throughout the mission life.

3.2 Derived Throughput Requirements, Molecular and Particle
Instrument contamination control requirements were derived from performance requirements of the instrument and spacecraft, and include hydrocarbon path length in the instrument optical path, internal and external instrument hardware surface cleanliness (particles and NVR), outgassing rates for the instrument exterior and allocated outgassing rates for sub-assemblies and components of the instrument interior and exterior.

3.2.1 Molecular
Molecular to meet EOL degradation limit of 50%.

Table 3-2a: Derived Cleanliness Requirements for Instrument Optical Path

EUV Wavelength, Å	Signal Attenuation	Total Organic Pathlength Thickness (Å)
171	50%	930
195	50%	795
284	**50%**	**495**
1550	50%	700
1700	50%	700

Table 3-2b. Hardware Surface Cleanliness Requirements (Particles & NVR)

Hardware Sub-System	**At Instrument Integration** (1,2)	**EOL**
Instrument Interior		
Non-Optical Surfaces	250 A/2	N/A
Front Entrance Filters	VCHS	50 Å
Isolated CCD (Tube & Shutter)	100 A/2 (3)	50 Å
Mirrors & Filters	VCHS (TBR)	50 Å
Guide Telescope Interior	300 A	N/A
Guide Telescope Exterior	VCHS	N/A
DPU Interior	N/A	N/A
DPU Exterior	VCHS	N/A
Instrument Exterior	VCHS	N/A

Notes:

(1) All cleanliness levels per MIL-STD 1246

(2) The exterior surface cleanliness requirement "VCHS," is specified as a precaution. Particles from these surfaces do not expose critical surfaces or views.

(3) Less than 0.1% total surface area coverage on CCD

Table 3-2c: TRACE Instrument Outgassing Rate ($OGR_{t°C}$) Limits (TBR)

	PHASE	
TRACE HARDWARE	SPACECRAFT INTEGRATION	ON-ORBIT BEGINNING OF LIFE
INSTRUMENT INTERIOR	1 x10^{-9} (1) (TBR)	1 x10^{-9} (TBR)
INSTRUMENT EXTERIOR	1 x10^{-8} (2) (TBR)	1 x10^{-8}
DATA PROCESSING UNIT		1 x10^{-8}
At vents	1 x10^{-8} (2) (TBR)	

Notes:

(1) Outgassing rates (OGR_{-65C}) are given as grams/cm^2-sec of material condensable on a -65°C

3.2.3 Contamination Budget

TRACE is an optically based instrument and is sensitive to contamination. Three areas create concern for the instrument performance; 1) molecular deposits, 2) particles, and 3) contaminants on the thermal surfaces. Molecular deposits on the optical elements could increase solar energy absorption or vary spectral transmission. Molecular contaminants degrade optics by causing attenuation, scattering and distortion of the spectral reflectivity function. Particles in the light path could degrade optics by causing a decrease in resolution or obscuration and an increase in light scattering. Contaminants on thermal surfaces could cause degradation in the thermal control surfaces to the extent that thermal control could be impaired. The most critical hardware components to be protected from contaminants are the entrance windows, CCD detector, and optical elements. The thermal control surfaces, both interior and exterior, are of secondary concern. Mechanisms, such as actuators and motors require precautions to ensure particles generated by their operation are vented and isolated from the critical elements, and that the lubricants used are low outgassing materials. The critical elements need protection from both self-contamination (within the TRACE instrument) and cross-contamination (from the spacecraft and launch environment).

3.2.4 Budget Allocation

The contamination budget allocations are based on TRACE throughput requirements and hardware flow. The budget is allocated to meet EOL performance requirements based on a maximum 50% degradation in the instrument transmittance. TRACE CCD on-orbit signal performance is monitored as a direct indication of accumulating contamination. Modeling are to be performed to provide a basis for predicting the deposition of molecular contamination on-orbit, and to predict the effects of contamination on the performance goals for TRACE.

Viewing 284Å will be done in a configuration with nine surface-intersections in the optical path . The per surface organic-pathlength allocation is not calculated, as the CCD is decontaminated on-orbit, as required. If deposition occurred on all surfaces equally, the limit for deposited material on each surface in the path (Entrance filter front and back, primary mirror entry and exit, secondary mirror entry and exit, filter wheel filter front and back, and CCD surface) would be 50Å.

Outgassing rates (condensable at the temperature of the coldest optical surface: -65ºC for the CCD) for Instrument hardware are allocated to assure that outgassing levels for the integrated telescope will be met. Table 3-2d is a summary of the instrument sub-system outgassing rate allocations.

Table 3-2d: TRACE Instrument Hardware Outgassing Allocation for Material Condensable at Given Temperature ($OGR_{t°C}$) (all TBR).

TRACE HARDWARE	PHASE				
	COMPONENT FABRICATION	INSTRUMENT INTEGRATION	SPACECRAFT INTEGRATION	LAUNCH VEHICLE INTEGRATION	ON-ORBIT BEGINNING OF LIFE (by analysis)
INSTRUMENT INTERIOR		1×10^{-9} (1)			1×10^{-9} (1)
ENTRANCE FILTER		1×10^{-9} (1)	1×10^{-9} (1)	1×10^{-9} (1)	1×10^{-9} (1)
Viton o-rings	1×10^{-9} (1)				
Entrance Filters (3)	1×10^{-9} (1)				
Filter Chamber Assy.	1×10^{-12} (1)				
SPIDER ASSEMBLY		1×10^{-9} (2)	1×10^{-9} (2)		
PZT	1×10^{-9} (2)				
Focus Motor	1×10^{-9} (2)				
Shutter aperture motor	1×10^{-9} (2)				
AFT SUPPORT ASSY		1×10^{-9} (1)			1×10^{-9} (1)
Triangle mount	1×10^{-12} (1)				
Invar/Siltex mount	1×10^{-9} (1)				
Filter wheel units	1×10^{-9} (1)				
Cable harness	1×10^{-9} (1)				
FOCAL PLANE		1×10^{-9} (1)			1×10^{-9} (1)
Shutter motor	1×10^{-9} (1)				
Isolator/cold trap	1×10^{-9} (1) (TBD)				
CCD sensor	1×10^{-9} (1) (TBD)				
Cable harness	1×10^{-9} (1)				
METERING TUBE		1×10^{-12} (1)			1×10^{-12} (1)
Tube sections	1×10^{-12} (1)				
Invar rods	1×10^{-12} (1)				
INSTRUMENT EXTERIOR			1×10^{-8} (2)	1×10^{-8} (2)	1×10^{-8} (2)
Guide Telescope	1×10^{-8} (2)				
Coarse Sun Sensor	1×10^{-8} (2)				
Digital Sun Sensor	1×10^{-8} (2)				
Cable harness	1×10^{-8} (2)				
Multi-Layer Insulation	1×10^{-8} (2)				
DATA PROCESSING UNIT			1×10^{-8} (2)	1×10^{-8} (2)	1×10^{-8} (2)

3.3 Hardware Surface Cleanliness Requirements

3.3.1 Optical Elements

3.3.1.1 Entrance Filters and MgF_2 UV Window

The entrance aperture is divided into quadrants, three of the quadrants are covered by thin aluminum entrance filters that transmit either 171Å, 195Å, or 284Å, and the forth quadrant is a magnesium fluoride filter that transmits UV and suppresses visible light. Molecular deposits and particles are of concern for the aluminum entrance filters and MgF_2 window, and the aluminum filters may oxidize. Oxidation and molecular contaminants degrade the spectral transmittance and could increase the level of solar energy absorbed and cause it to exceed the thermal design limits. Particles could increase scatter and degrade transmittance.

To prevent contamination of flight filters, engineering filters are installed during all phases of assembly, integration and test, and are only replaced in the instrument with flight filters immediately prior to captive-carry. Flight filters are fabricated, visually inspected for cleanliness, and stored in a specially built and cleaned container that is backfilled with clean dry nitrogen to prevent contamination or oxidation. As there is no sampling method which is satisfactory to verify a specified quantity of molecular and/or particle cleanliness of this surface, (JSC SN-C-0005) a cleanliness level of VCHS is applied. Cleanliness is assured by delaying the installation of flight aluminum filters until immediately prior to launch.

Engineering filters are in place during all phases of ground-operations, and are replaced by flight-filters prior to launch where the vacuum environment of the FCA protects the filters during launch. The FCA front and back doors are closed during launch, and the front doors are opened first during early on-orbit operations to allow the sun-warmed entrance filters to outgas. The closed back doors will assure that outgassed materials may vent to space.

3.3.1.2 Focal Plane, CCD Detector

The 1024 x 1024 CCD camera has a pixel size of 21 microns, and operates at -65°C. Particle obscuration and organic deposits are contamination concerns for the CCD detector; particles obscure pixels, and molecular condensation decreases transmittance and may affect the performance of the lumogen coating. Exposure of the CCD to molecular contaminants is reduced by instrument and operational design considerations, component or subsystem pre-processing, and by verification. These include the following:

1) screening criterion for materials is TML <1.0% and VCM <0.1%;

2) outgassing is verified to be reduced to allocation levels by thermal vacuum bakeouts with TQCM monitoring;

the telescope interior via 3 sintered metal ascent vents and/or labyrinth path between the entrance filter filter-frame and the filter-chamber;

5) placement of molecular adsorber in the body of the instrument to absorb outgassed materials during on-orbit life, as required;

6) on-orbit operations include the ability to warm the CCD (+50°C) for decontamination purposes;

7) and controlled environments and handling during assembly and ground-operations.

Particle contamination of the CCD is controlled by design, cleaning, and operational means, including:

1) interior surfaces of the CCD Isolation tube, and the CCD face are verified clean to level 100;

2) closing the shutter and placing filter-wheel filters across the aperture through the primary mirror effectively isolates the surface of the CCD from particle redistribution during shake test, acoustic tests, and launch by obscuring the fall-path from the main volume of the telescope;

3) assembly and test in a FED-STD 209 Class 1,000 cleanroom or LFB, or better; and

4) protective packaging, caps, and/or covers during storage and during inactive phases between testing or assembly operations.

If necessary, however, two cleaning methods have been shown effective: acetone flush, and manual particle removal using a polyester-tipped probe under magnified viewing.

CCD sensor particle contamination level is verified by direct performance measurements of the CCD and by visual inspection of the surface with magnification of at least 100x. A method developed by Solar A SXT to document particles on the face of the CCD by computer analysis of a dark image is used. Micro-photography (100x to 400x) is used to document the condition of the CCD face, as received and immediately prior to installation into the flight-camera system. Analysis of particulate contamination from these methods are used to quantify the contamination on the CCD surface. Extrapolation to MIL-STD 1246 levels is performed.

3.3.1.3 Mirrors

Transmission through the optical path – multi-layer optical elements including the primary and secondary mirrors and optical filters – is degraded by particles and molecular contamination.

stored in a clean, dry, nitrogen environment, which is monitored using OWS mirrors as described in the Mirror OWS monitoring plan (TRA-271016). Following integration of the mirrors with the instrument, the nitrogen-purged interior of the telescope is monitored using OWSs to assure the cleanliness of that environment. The OWS monitoring plan after instrument integration is described in the Instrument OWS Monitoring Plan (TRA-271016).

For control of particle contaminants, mirrors are maintained clean during storage, assembly, and by the cleanliness of the telescope interior. Interior telescope surfaces (non-optical) are cleaned and inspected to assure compliance with Mil-Std 1246 Level 250 A/2, as required, prior to the installation of optical elements. Optical elements are handled only in FED-STD 209 Class 10,000, or better, cleanroom or laminar flow bench. Optical component surfaces are visually inspected to meet VCHS inspection and are capable of being cleaned as a contingency in the event of contamination during ground-operations.

3.3.2 Instrument Interior

3.3.2.1 Mechanisms (e.g.: Shutter and Aperture Shutter Motors, Filter Wheels, Focus Mechanism, PZT, and Wax Actuators) TRACE Instrument requires mechanisms for on orbit operations. These are used to open the doors, perform alignment and focus, calibrate EUV band-pass, select mirror quadrants, regulate exposure time, and operate the guide telescope. The mechanisms are designed to minimize particle generation and molecular outgassing, and isolate these products from the critical optical surfaces. Design features include isolation in component boxes, use of materials with low outgassing, and verification with thermal vacuum bake-out. Only approved, low-outgassing lubricants are used. OWS monitoring will be performed to assure that no contaminating events have occurred during ground operations.

3.3.3 Exterior

3.3.3.1 Electronics Package Exterior

Electrical and power sub-systems are isolated from optical components and other critical surfaces to prevent cross-contamination by outgassed material from electronic components. Cleanliness controls and procedures are imposed to ensure the electronics package exterior meets VCHS surface cleanliness, and $OGR_{20^\circ C}$ is verified to meet $10E^{-8}$ g/cm^2-sec (TBR), at integration with the spacecraft.

3.3.3.2 Multi-Layer Insulation

Thermal blankets are entirely sealed except at the anti-sun edge to direct outgassing products away from the critical sensors. MLI blankets are fabricated and assembled using contamination control techniques that avoid entrapment of particles, and are verified to meet $OGR_{20^\circ C}$ of $10E^{-8}$ g/cm^2-sec (TBR) by TVB with TQCMs.

3.3.3.3 Instrument Exterior

Contamination on thermal control surfaces is of concern because particles and molecular films change thermal properties of surfaces, and reduce power output of solar-cells. Exterior thermal surfaces are cleaned and verified to meet SC-N 0005 VCHS, and handled in a FED-STD 209 Class 100,000 or better, clean environment, and will be verified in thermal vacuum bake to meet outgassing rate ($OGR_{20^\circ C}$) of $10E^{-8}$ g/cm^2-sec (TBR).

3.4 Contamination Control Summary

The cleanliness requirements for the optical elements, instrument interior and exterior surfaces, and a summary of contamination control methods to attain and maintain these required levels, are in Table 3-4.

3.5 Support Equipment

Section 4
CONTAMINATION CONTROL IMPLEMENTATION

4.0 Contamination Control Approach

The approach to contamination control for the TRACE Program is cost-effective and straightforward. This approach contains three elements: (1) design the overall experiment and associated hardware to eliminate or minimize sources and effects of contamination wherever possible, (2) incorporate adequate cleaning and inspection procedures at appropriate points in the hardware build-up sequence, and (3) maintain the TRACE cleanliness levels by the use of appropriate protective measures throughout the life of the experiment, from initial manufacture and assembly, to delivery.

The contamination control implementation plan, in the hardware flow, is shown in Figures 4-1a, b, and c (pp. 27-29 of this plan). Details are described in cleaning, verification, thermal vacuum bake, purge, and monitoring plans cited in this document.

4.1 Management Approach

The management of the TRACE Contamination Control Plan involves a coordinated approach to engineering, production, PA, and subcontractors and suppliers. A Contamination Control Engineer (CCE) is appointed to have a lead role in all contamination related activities.

4.1.1 Engineering

Engineering control is implemented through design review and design release of all drawings and documents which affect contamination control as required by this document. Guidance for design engineering is provided by evaluation of potential material applications, proposed design configurations, ground operations and test procedures, and on-orbit operations for opportunities to control and prevent contamination of critical surfaces.

4.1.2 Production

Contamination control requirements are implemented by shop orders, log books, job package authorizations, engineering test procedures and plans, and TRACE acceptance and systems test procedures.

4.1.3 Product Assurance (PA)

Hardware cleaning and cleanliness verification, and cleanroom/LFB certification and monitoring is performed by the LMMS Contamination Control Engineering and Laboratory, O/48-50. Results of monitoring are reported to TRACE Product Assurance for inclusion in existing TRACE Product Assurance documentation. PA verifies compliance to all program requirements and that the intent of the contamination control plan achieved. When process or personnel certification is required, PA provides that the hardware supplied be clean, as defined, when introduced into the system, regardless of the approach utilized. Off-the-shelf hardware also meets the contamination control requirements of the hardware to which it is installed.

4.2 Sources of Contamination

Contamination is described as either particles or molecular. Some sources of contaminants are:

4.2.1 Particles:

- Airborne particles, skin flakes, hair fragments, wear-generated material from clothing, and other human detritus.
- Paint flakes, metal particles, and other forms released or generated by hardware or GSE.
- Particles in the payload compartment of the launch vehicle that are loosened and re-distributed during launch.
- Particles dispersed by opening and jettisoning of launch vehicle nose-fairing.
- Trapped particles on or in the experiment package that are released and redistributed during launch.

4.2.2 Molecular Contaminants

- Lubricants, fluid leaks, and exposed organic material which permit volatile condensable material to be transferred to critical surfaces.
- Deposition of gaseous components and organic or inorganic material arising from outgassing or outgassing.
- Molecular cloud environment generated by operations and outgassing of experiment equipment and launch vehicle surfaces.
- Return flux of outgassed molecules caused by collisions with residual atmospheric molecules and self-collisions.
- Contamination from spacecraft subsystem or from the deployment of these subsystems.

4.3 Design Considerations

The approach for the TRACE program is to minimize the sources and effects of contamination through hardware design and material selection. This is accomplished by imposing different requirements on different hardware zones. Flight hardware and interface support equipment is cleaned as necessary during pre-launch assembly, test phases, and storage. Preventive design features are discussed in the following sections.

4.3.1 Materials Selection – Metallic Materials

Cadmium, zinc, and un-fused electrodeposited tin are not used on any item(s) that reside on the TRACE instrument. Dissimilar metal combinations are avoided or protected to meet the requirements of MIL-STD 889. Corrosion resistant materials are used to the maximum. The materials and processes used in the manufacture of the hardware are listed in the authorized materials and processes documentation. Materials susceptible to corrosion are coated for corrosion protection.

the adhesive qualities of the protective films. Process controls are invoked at all stages of finishing operations to check for the presence of contaminants in processing solutions and baths, surface preparation techniques, and final finishing processes.

4.3.2.2 Thermal Vacuum Stability of Non-metallic Materials

All materials used in the TRACE flight hardware meet the thermal vacuum acceptance criteria as specified herein. Flight hardware and GSE materials that are exposed to vacuum environment during ground test or on-orbit, have materials selected with consideration of their outgassing characteristics. Proposed materials are screened per (JSC) SP-R 0022A to not exceed total mass loss (TML) of 1.0%, and volatile condensable material (VCM) content of 0.1%, when tested in accordance with ASTM E595. Analysis of material outgassing per ASTM E1559, at temperatures more representative of the hardware operating temperatures, outgassing data previously generated for proposed materials under conditions similar to hardware operating conditions, and conditioning processes previously employed are used where applicable. Materials and assemblies are thermally conditioned to reduce outgassing rates, and have $OGR_{t^{o}C}$ verified by thermal vacuum bakeout (TVB) prior to being incorporated in instrument hardware. Verification and analysis are performed to ensure all materials have been selected and conditioned to eliminate the possibility of introducing harmful levels of condensable molecular contamination to the critical hardware surfaces.

Materials that do not meet JSC SP-R 0022A requirement, and which are used in areas that do not expose critical surfaces, are approved for each design application by means of a Materials Usage Agreement (MUA). Materials used in areas which expose critical surfaces are approved by verifying outgassing rates with TQCMs.

4.3.2.3 Chemical Compatibility in Hardware & Process Materials

Adhesives that generate acetic acid as a part of their curing process are not used. Cleaning solvents are selected and specified in appropriate manufacturing instructions to preclude the effects of swelling, grazing, lifting, or compromising the physical integrity of the items being cleaned. Cleaning materials (wipes, swabs, gloves) are tested to ensure they are compatible with the cleaning solvent used and do not leave nonvolatile residues on the hardware.

4.3.2.4 Contamination Resistant Materials and Treatments.

Hardware design activities emphasize the use of materials and finishing systems that are easily cleanable and which do not produce contaminating or corrosive by-products. The primary materials and treatments avoided are as follows:

- In zones where control of particle contamination is critical, textured finishes, such as inorganic paints, sanded or shot-peened surfaces, which retain particles and do not respond to vacuum or solvent cleaning, are avoided;
- Adhesives that yield corrosive by-products, such as acetic acid or formaldehyde, as a part of their curing process are not used;
- Polymeric, organic, or lubricant materials in the instrument interior, or near thermal control surfaces, which have not met required $OGR_{t°C}$ allocated levels for that zone.

4.3.3 Design for Cleanability

In addition to the materials selection effort, special attention is paid to design parameters to provide for component cleanability and minimize contamination inclusions. For example:

- Avoiding inaccessible or hidden areas;
- Development of hardware-flow with cleaning points planned, and providing access for cleaning;
- Providing protective shields, caps, and covers to minimize exposure to contamination in critical areas, and during operations or procedures which might re-distribute or generate contamination;
- Hardware-flow planning which includes final cleaning and verification of components immediately prior to integration, if further cleaning is not possible in the integrated configuration;
- Encapsulating motors in paraylene;
- Avoiding fasteners which entrap particles.

4.3.4 Design for Protection

4.3.4.1 Instrument Interior Venting and Nitrogen-Purge Design

TRACE instrument vent-path, door, and aperture configuration and locations are controlled to exclude molecular contaminants during ground-operations and on-orbit, and to provide an environmentally controllable zone in the interior of the instrument. Storage and shipping containers for individual optical components and sub-systems are designed to provide clean, controlled, and monitored environments. Monitoring devices are used to assure that control of the environment has been maintained during shipping, storage, ground-operations, and testing. OWS Monitoring Plan (TRA-271016) for the Telescope interior and the TRACE Instrument Purge Plan contain monitoring details for these conditions.

Purge is described in TRACE Instrument Purge Plan (TRACE-PROC-091), and will be with clean, dry, nitrogen that meets the following requirements, at a minimum: Mil-C 27401 Class B; <1.0 ppm total hydrocarbon; and =5.0ppm H_20. At a minimum, requirements for the purge plan include: 1) shall last less than 5 hours, total, for handling. In addition, TRACE instrument, and instrument integrated with the spacecraft, is in a sealed bag to further protect the interior environment, and reduce the purge-flow required

4.3.4.2 Contamination Barrier and Cold-Trap Design

TRACE Instrument is designed to limit self-contamination through use of barriers and traps which restrict the re-distribution of contaminants from critical surfaces. Particles are blocked from falling into the focal plane area by closed shutters and by rotating the filter wheels to positions which block the aperture between the main volume of the telescope and the focal plane. Traps, corners, and blind holes that collect particles during manufacturing and assembly are also avoided by design. For example, mounting holes are through-holes rather than blind holes. Also, charged surfaces are not adjacent to critical optics, when possible.

Exposure of optical elements to condensable materials is reduced by isolation (especially from the exterior environment), protective covers or compartments, and baffled vents. The deposition of molecular contamination onto the CCD is reduced during on-orbit operation of a cold-trap that encircles the CCD sensor as a tube, and provides a non-critical condensing surface which intercepts material which would otherwise be available to condense on the CCD surface. Molecular adsorber is included in the telescope interior, if required.

4.3.5 Protection by Monitoring with Witness Samples

Witness samples are used as incremental indicators of condensed material when direct sampling is not possible. Witness samples will accompany each mirror through all phases, from initial fabrication / coating through installation in the instrument. OWS Monitoring of the telescope interior is described in the OWS Monitoring Plan (TRA-271016) Optical witness samples (OWS) are analyzed by V/UV at baseline and after exposure, and the difference in reflectance is calculated and used as an indicator of the presence of condensed molecular contaminants from the sampled environment. OWS are also used in purge-systems, thermal test cycles, and thermal vacuum bakeouts as appropriate for monitoring and/or outgassing verification.

4.5 Fabrication and Assembly

During fabrication and assembly, components of the experiment requiring surface cleanliness consideration are not compromised by exposing them to work areas that do not support the level of cleanliness for those items. It is important to realize that even though the flight hardware is processed in certified cleanrooms, it may be necessary to re-clean the items periodically to maintain the required cleanliness levels.

4.5.1 Fabrication/Assembly Sequence and Processes

The hardware fabrication for the TRACE equipment, except for the optical components, is performed in the general manufacturing shop areas. Hardware that must be fabricated in special environment areas to attain a specified cleanliness level is identified to ensure that proper precautions are taken. Processes used during fabrication and assembly operations may contribute to contamination problems invoked for all processing operations to be employed during hardware fabrication and assembly. Precision cleaning is performed on specific items as defined by program requirements. Components or structural hardware are individually packaged and stored in clean, non-oily, non-contaminating bagging material while awaiting installation in the system. After installation, surfaces are subjected to the same cleanliness protection and inspection requirements as those invoked on the assembled system.

4.5 Cleanroom Facilities

4.5.1 Facility Requirements

The requirements for clean areas varies with the need to attain and maintain a specific level of cleanliness, and vary with the requirements of particular hardware items, however as stated in paragraph 3.1, all facilities are certified to FED-STD-209. All facilities are verified before contamination-sensitive hardware is exposed by air sampling for particles, temperature and relative humidity to determine compliance with facility requirements. They require 99.99% efficiency minimum air filtration (HEPA), temperature control 68-78° F and relative humidity 20 - 60, with room pressure 0.05 inch water minimum and <60 room air changes per hour. When critical surface areas are in final precision cleaning operations, testing, calibration or packaging; the area environmental requirements are as shown below, Table 4-5a .

Table 4-5a. Environmental Area Requirements

REQUIRED SURFACE CLEANLINESS LEVELS	CORRESPONDING ENVIRONMENTAL REQUIREMENTS
MIL-STD-1246 Level 100A or better	FED-STD-209 Class 1,000 or better
MIL-STD-1246 Level 300A or better	FED-STD-209 Class 10,000 or better
MIL-STD-1246 Level 500B or better	FED-STD-209 Class 100,000 or better
Visibly Clean, Highly Sensitive	Special Cleanliness Area or better

4.5.1.1 Certified Cleanrooms

Cleanrooms are available at various locations within LMMS for use in cleaning/processing of critical hardware. These rooms vary in certification levels from Class 100 through Class 100,000 per FED-STD-209. The areas listed in Table 4-5b are to be used for the majority of the TRACE processing and testing.

Table 4-5b. Certified Cleanrooms Available for TRACE

B/252	Laminar Flow Bench (LFT 090958)	1,000
B/252	Laminar Flow Bench (LFT M090900)	1,000
B/252	Laminar Flow Bench (LFT M090959)	1,000
B/252	Laminar Flow Bench (LFT 81502)	1,000
B/202	Cleanroom (100 area)	100
B/202	Cleanroom (10,000 area)	10,000

4.5.1.2 Special Cleanliness Areas

Special cleanliness areas incorporate controls and procedures that result in the exclusion of visible contamination on the product. The area environment is between cleanroom conditions and a conventional industrial area with a cleanliness goal for the equivalent of Class 300,000. They require 95% efficiency minimum air filtration, temperature control 68-78° F and relative humidity 20 - 60, with room pressure 0.05 inch water minimum and 5 - 10 room air changes per hour. Good housekeeping practices (no smoking, drinking, eating, etc.), increased janitorial activities and certain operational constraints are imposed. These areas are used as intermediate zones around some of the laminar flow tents and benches that operate at Class 1,000 within a conventional industrial area.

4.5.2 Facility Operations

Procedural controls are imposed on all operations performed within cleanrooms and on all equipment, supplies, or tools that are taken into the cleanrooms to minimize particulate generation and molecular outgassing. There are operational designated activity areas in B/202 and B/252. Specialized areas are provided for pre-cleaning of tools and equipment destined for use in the cleanrooms. Change rooms or areas are provided at the entry to the cleanrooms or clean tents which include tacky mats, shoe brushes, and inventoried cleanroom garments storage. These areas are used only for donning cleanroom garments by personnel, and to provide entry for tools and equipment into the room if there is not an additional pre-clean area.

4.5.2.1 Certification of Cleanrooms

Cleanrooms are certified in accordance with LMMS Product Assurance Std 8620-Q002, while the room is in an operational mode, with all equipment turned on and functioning normally, and the assigned complement of personnel in the room simulating work. Particle counts are determined through the use of Automatic Particle Counting (APC) systems capable of sizing and counting particles 0.5 microns and larger, as defined by FED-STD-209.

4.5.2.2 Facilities Monitoring

Particle counts, temperature, relative humidity, personnel activity level, air flow velocities and HEPA filter pressure differential are monitored by LMMS O/48-50 on a monthly basis. Results of this monitoring and of periodic surveillance of cleanroom operations is recorded on laboratory reports provided to Product Assurance for validation purposes. Particle fallout witness plates will be placed at critical locations adjacent to flight hardware when mirrors or CCD are exposed. The analysis for the witness plates will be used to measure long duration cleanroom exposure. The results will be utilized by the TRACE CCE to assess the effects of particle fallout on TRACE equipment exposed to these working environments. Condensable materials will be monitored using large (12x12") stainless steel plates which will be tested for NVR, or by other approved methods.

response to the following possible causes:

- Loss of facility power
- Loss of air handling system fans
- Loss of air conditioning
- Room pressure differential is low
- Airflow velocity and volume are low
- Leak in filter media or filter gaskets

4.5.2.5 Facility Maintenance
In this context, the term "maintenance" refers to the actions necessary to maintain the cleanroom surfaces in as pristine a state as possible. Such maintenance includes damp-moping or damp-wiping of all work surfaces within the cleanroom, vacuuming of floors and bench tops, and removal of all trash from the room. This is performed on a regular basis, in accordance with LMMS standard cleanroom guidelines.

4.6 Hardware Cleaning Methods
4.6.1 Personnel Training
Special training is conducted for personnel requiring access to clean areas. Only personnel who have received cleanroom orientation and are authorized by the area supervisor are permitted to enter the cleanroom. Personnel training includes the following subjects:

- Gross cleaning versus precision cleaning
- Special vehicle cleanliness requirements
- Description of cleanrooms and devices
- Cleanroom operational supplies
- Personnel constraints
- Cleanroom orientation and facility constraints
- Entry and exit procedures for personnel and hardware

4.6.2 Hardware Cleaning Techniques
Hardware cleaning procedures applicable to the cleaning of structures and equipment are described in LAC 3150 and 3155. All precision cleaning procedures used at LMMS for vehicle hardware are verified by test. TRACE CCE, in coordination with TRACE Engineering, reviews and approves appropriate techniques for cleaning and verifying TRACE hardware. Effective precision cleaning of hardware are planned and implemented. Consistent cleaning results are achieved by using cleanroom personnel trained and certified for precision cleaning and hardware verification. Verification surface cleanliness levels is performed by O/48-50 or TRACE personnel who are trained in hardware verification techniques. Cleanliness verification methods are shown in Table 4-1. Experiment structures and equipment are designed to be compatible with the following solvents and aqueous cleaning procedures that have been developed.

verification methods to be used relative to the contaminant type.

Table 4-7. Cleanliness Verification Methods

Method	Particulate	Molecular
Solvent Flush Method (ASTM F303)	Yes	Yes
Solvent Wipe Method (LAC 3155)	No	Yes
Vacuum Collection Method (LAC 3155)	Yes	No
Tape Lift Method (ASTM E1216)	Yes	No
TQCM Monitoring	No	Yes
Visual Inspection	Yes	Yes
Optical Witness Sample (OWS) Monitoring	No	Yes

Surface cleanliness of the TRACE exterior is verified prior to shipment to the integration site. The methods of cleanliness verification include: (1) verification by procedure, (2) verification by test and (3) verification by hardware performance.

4.7.1 Verification By Procedure

The method of surface cleanliness verification that is most cost-effective is to selecting a process for cleaning and verifying that the cleaning process produces the desired cleanliness level. Validated processes are used on TRACE electronics, optical elements, mechanisms, and internal mechanical and structural surfaces.

4.7.2 Verification by Test

Surface cleanliness verification is performed on precision cleaned hardware surfaces. Specific cleanliness levels are verified by using an LMMS approved cleanliness verification method, as listed in Table 4-7.

4.7.3 Verification by Performance

Cleanliness of the optical path is verified by measurement of instrument performance on-orbit.

4.7.4 Compliance to Cleanliness Requirements

Product Assurance verifies that the cleanliness data for specified hardware components and assemblies meet the applicable MIL-STD-1246 or JSC SN-C-0005 cleanliness level, and are in compliance with the program goals.

4.8 Protective Packaging

The constraints planned for the TRACE contamination program operations are intended to build operations or storage.

4.8.2 Packaging Material Requirements

All packaging materials must be approved by TRACE Engineering prior to use. The following constituents are used to determine acceptability of packaging films:

- Surface cleanliness meeting the requirements of MIL-STD-1246, Level 100
- Low outgassing materials
- Electrically conductive to drain off static charges (for electrostatic-sensitive parts only)
- Partially transparent

4.8.3 Packaging Approach

Unless otherwise specified, a clean electrically conductive laminate will be used as a "first barrier". Teflon or nylon will be used as a second barrier to maintain surface cleanliness. The outer wrapping is polyethylene or other approved material to provide protection against moisture intrusion. Heat sealing will not be permitted since TRACE is a molecular contamination sensitive instrument. The packaging materials will be tape sealed with clean nylon or polyethylene tape to meet contamination control requirements.

Packages are identified as to contents and cleanliness levels. Such identification is placed between the inner and outer bags, and is visible for purposes of inspection without removing the outer bagging. In the event that non-transparent outer packaging is applied, the identification is applied to the outside of the packaging, in a transparent, weather-proof envelope.

4.9 Transportation

There are two areas of concern in the transportation of TRACE hardware. One concern is with movement of critical hardware within LMMS when it is necessary to remove it from the cleanroom. The second is in relation to transportation to a remote site.

4.9.1 Moving Hardware Within LMMS.

Whenever precision-cleaned components, hardware, and subassemblies are removed from the cleanroom and moved to another location, protective packaging is utilized that consists of the following:

- Inner bag of cleanroom nylon bagging ("first-barrier cover"). Moisture-sensitive hardware contained in the inner bag is purged with clean (cleanliness level determined by the type of hardware) dry nitrogen, and/or contain dry desiccant packs between the inner and outer bagging material prior to sealing.
- Outer bag of polyethylene (moisture barrier)
- Protective shipping container, to provide physical protection against damage.

4.9.2 Transportation to Integration and Launch Sites

Contamination control during transportation to a remote site is described in TRACE Instrument Purge Plan (TRACE-PROC-091), and includes protective shipping container and bagging in clean packaging such as described in section 4.9.1. In addition, a shipping container with dry desiccant is utilized to provide necessary protection while at the same time maintaining hardware cleanliness levels. Venting of the shipping container is provided to release any excess pressure that might be created during exposure to the shipping environment. Venting design incorporate micron filters to exclude particulate contaminates during changes in ambient pressure.

4.10 Systems and Component Test

All systems test operations are carried out in an atmosphere that maintains the required system cleanliness level. Should it be necessary to perform test outside the protective atmosphere, all hardware is packaged and sealed to maintain cleanliness.
Systems tests with critical surfaces exposed are carried out in a cleanroom meeting the requirements of an atmosphere that maintains the critical surfaces cleanliness requirements. In the event that tests are required that cannot be performed in the cleanroom, such as the vibration test, the instrument is protected with packaging per section 4.9.1, nitrogen purge or backfill, and OWS monitoring. All

possibility of compromising critical hardware during a thermal vacuum test or bakeout, chamber cleanliness must be assured In addition, to minimize redistribution of outgassed material onto flight hardware from any source, chamber operations and test plans are reviewed and approved by TRACE CCE in coordination with TRACE Engineering Requirements and procedures for thermal vacuum chamber operations, chamber certification, monitoring methods and procedures, and test procedures for contamination control are described in TRACE Instrument TV/TB Plan (TRA-271011), and in Spacecraft TV/TB and TVB Plan (TRACE-TEV-O28).

4.11.1 Thermal Vacuum Chamber Preparation

Chamber preparations are described in TV/TB and TVB test plans, and include, as a minimum:

- Thorough solvent wipe of the interior of the test chamber and associated cabling and test fixtures;
- All test GSE hardware must be made using low-outgassing materials per ASTM E-595, or conditioned to meet low outgassing requirements;
- Chamber is equipped with a liquid nitrogen or liquid helium cryo-wall which is flooded during chamber certification, and hardware TV/TB and TVB.
- Optical witness samples (OWS) are placed strategically in the chamber during the test, removed, and analyzed by V/UV at 1216Å are used to detect condensable contamination in the chamber;
- Foil witness samples attached to the cryo-wall may be used as additional witness samples;
- Collectible volatile condensable materials are monitored in real-time with multiple thermal-controlled quartz crystal microbalance (TQCM);
- Chamber molecular flux levels are verified to be below required $OGR_{t^\circ C}$ rates during chamber certification, prior to thermal vacuum operations with flight hardware;
- Chamber certification will be performed with all GSE (framework, heaters, thermocouples, wiring harnesses, etc.) in place inside the chamber;
- Measured temperature of GSE during chamber certification, is 10° C higher than the planned flight hardware bakeout temperature.

If chamber certification is unsuccessful in a reasonable amount of time, the chamber is cleaned and re-tested. Only after the chamber and support hardware show sufficient cleanliness is the chamber certified for flight hardware. Prior experience with thermal vacuum chambers at LMMS demonstrates that particulate and molecular contamination can be significantly minimized by carefully controlling chamber operational parameters and adhering to documented test procedures.

4.11.2 Component, Assembly, and System Thermal Vacuum Tests

A thermal vacuum test is performed only when the chamber has been qualified and TVB or TV/TB test plan has been approved by TRACE Engineering and TRACE CCE. The hardware is un-packed and placed in the chamber for testing. During this test period, witness samples are situated in close outgassing materials and hardware, which are major contributors to molecular contamination, are baked out to reduce production of condensable material. Temperature of TVB operations is 10 to 20°C above the highest anticipated operating temperature of the hardware, if possible, and progresses with real-time monitoring by TQCMs, until $OGR_{t°C}$ is at or below allocated levels. This increase in bakeout temperature assures minimal outgassing from the hardware on-orbit and reduce the risk of contaminating other sensitive hardware. Active and passive contamination control monitoring devices, like TQCMs, RGA and temperature-controlled OWS may be used.

4.12 Captive Carry and Launch Considerations

Captive carry and launch procedures and facilities are discussed in TRACE purge plan and ICDs (TRACE-PROC-091; TRACE-ICD-006).

4.13 On-Orbit Considerations

On orbit contamination control is discussed in mission operations and in the design sections of this implementation plan.

Figure 4-1a: Contamination Control Implementation Summary

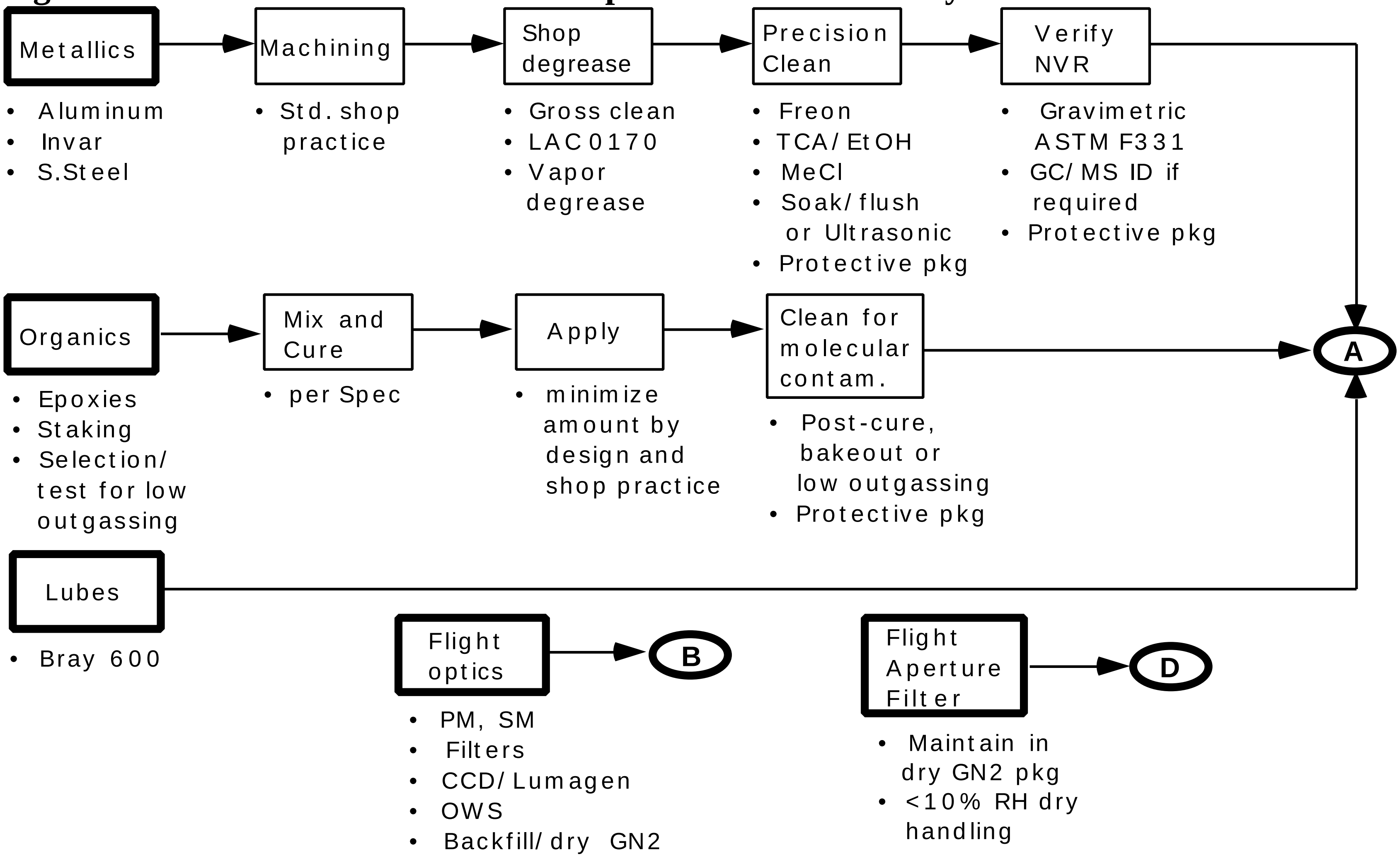

Figure 4-1b: Contamination Control Implementation Summary, *continued*

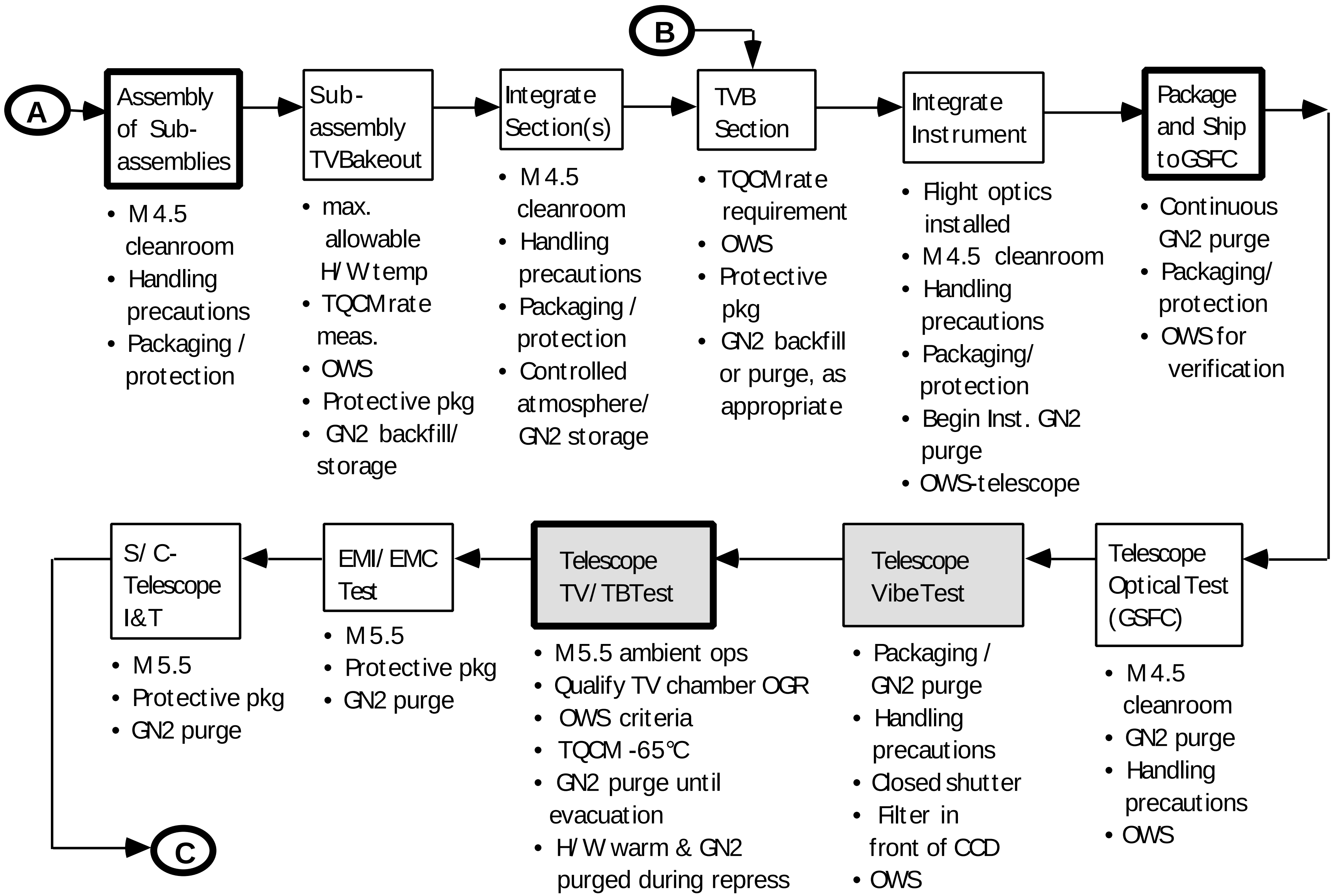

Figure 4-1c: Contamination Control Implementation Summary (*continued*).